SECTION 2. SUBSURFACE INVESTIGATIONS

3. GENERAL REQUIREMENTS. An investigation of subsurface conditions such as that normally made for foundation design purposes is usually sufficient to determine whether unfavorable conditions are present that can be improved by grouting. The discovery of any of the following in the course of these investigations warrants consideration of treatment by grouting if the success of the project could be affected thereby: soluble rocks or evidences of solution activity, prominent open joints, broken or intensely jointed rock, faulting, losses of circulation or dropping of drill rods during drilling, or unusual groundwater conditions.

4. SPECIAL REQUIREMENTS.

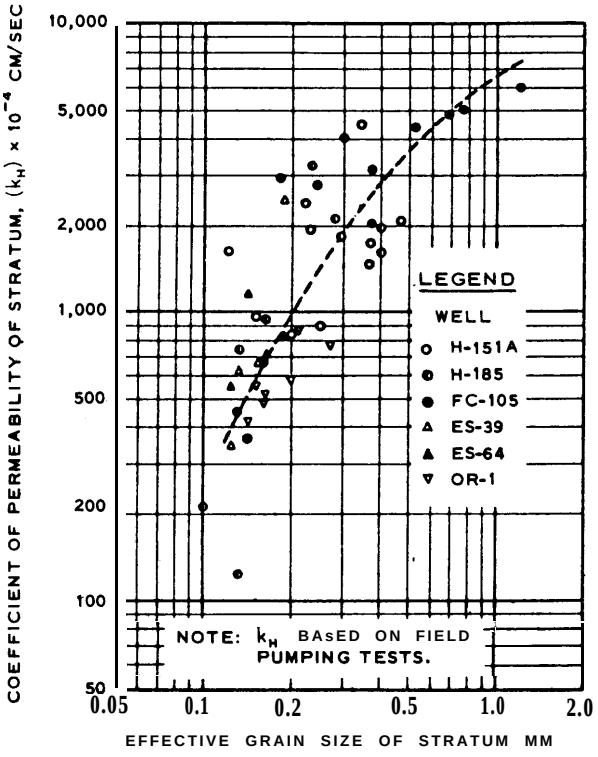
a. Exploratory Borings. Specific information on subsurface conditions is needed to plan the grouting program. In order to determine the scope and estimate the costs of the drilling and grouting operations in rock, information on orientation, attitude and spacing of joints, joint openings including type of filler if any, boundaries of rock types, location of faults, location of broken zones, depth to sound rock, and position of water table should be available. The borehole camera or television camera can be of particular assistance in obtaining this information. If soil is to be grouted, information on its stratification, density, grain size, and permeability will be required. If these data, as pertinent to the project, cannot be obtained from the design investigations or from rock exposed by the first excavation at the site, additional explorations (borings, trenches, etc.) should be made to supply the missing data.

b. Field Tests.

(1) Pressure tests. Pressure testing by pumping measured amounts of water into exploratory boreholes under known pressures serves a useful purpose if the injection of gel-forming grouts is contemplated. The results of the pressure tests will show the permeability of the soil or rock mass to water or other fluid of the same viscosity. The best way to determine the permeability of uniform, porous, water-bearing soil layers is by a pumping test, as discussed in Civil Works Technical Letter 63-16. Pressure testing of rock to learn whether it will accept a cement or clay grout is rarely worthwhile. If pressure testing is done for this purpose each tested increment of borehole should be examined by television or borehole camera to obtain information on the size of the openings that are presumed to take water.

(2) Test grouting. The most reliable means of obtaining realistic answers to questions on the capability of rock to take a grout containing solids in suspension is by test grouting. The test-grout program should be planned not only to provide information on the groutability of the rock, but also on the

most suitable mixes and probable quantities of grout, if the rock takes grout. Although recommended for the purpose stated, test grouting is seldom considered necessary if only cement grouting of rock is involved. Collective experience from scores of jobsites where cement grouting was performed in widely varying subsurface situations indicates that cement grout can be injected if one or more of the conditions listed in paragraph 3 has been found in preconstruction investigations. Test grouting of soils with chemical grout coupled with exploratory trenches and pits to observe the results is very helpful in estimating costs and effectiveness, and on large jobs may allow a considerable saving of costs to be made if representative areas are tested. By varying grouting techniques, optimum spacing of holes, pressures, injection rates, and setting times can be ascertained for each major set of conditions. This permits obtaining satisfactory coverage with minimum quantities of drilling and grout.



(From "Investigation of Underseepage and its Control, Lower Mississippi River Levees," TM 3-424, Vol 1, Ott 1956, U. S. Army Eng. Waterways Exp. Sta.)

Figure 1. D_{10} versus in situ coefficient of permeability-Mississippi River Valley Sands

c. Laboratory Tests.

(1) Permeability. Test procedures for determining the permeability of soil samples are described in EM 1110-2-1906. Laboratory permeabilities are generally somewhat smaller than field permeabilities determined from field pumping tests.

(2) Gradation. Procedures for performing grain-size tests are given in EM 1110-2-1906. The effective grain size (D_{10} size) of Mississippi River alluvial sands has been correlated with field permeability values and the results of this correlation are shown in figure 1.

(3) Density. The density and void ratio of undisturbed samples should be determined for use in making calculations and in evaluating the stability and permeability characteristics of the in-place soil mass. Test procedures are outlined in EM 1140-2-1906.

(4) Chemical tests. Chemical analysis of groundwater samples should be made to determine the presence of calcium sulfate, magnesium sulfate, sodium sulfate, organic or mineral acids, and alkalies that may be detrimental to cement or chemical grouts. The pH of the water should also be determined.